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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/693,418	10/20/2000	Brian M Burmaster	ENV 9851.1	1265

321 7590 03/06/2003

SENNIGER POWERS LEAVITT AND ROEDEL  
ONE METROPOLITAN SQUARE  
16TH FLOOR  
ST LOUIS, MO 63102

EXAMINER
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VANOY, TIMOTHY C

ART UNIT	PAPER NUMBER
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1754

DATE MAILED: 03/06/2003

14

Please find below and/or attached an Office communication concerning this application or proceeding.

# Office Action Summary

Application No.

09-693,418

Applicant(s)

BURMASTER ET AL.

Examiner

VANDY

Group Art Unit

1754

— The MAILING DATE of this communication appears on the cover sheet beneath the correspondence address —

## Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE THREE MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, such period shall, by default, expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133).
- Any reply received by the Office later than three months after the mailing date of this communication, even if timely, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

## Status

- ☒ Responsive to communication(s) filed on DEC 17 2002
- ☐ This action is FINAL.
- ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11; 453 O.G. 213.

## Disposition of Claims

- ☒ Claim(s) 1-42 is/are pending in the application.
- Of the above claim(s) \_\_\_\_\_ is/are withdrawn from consideration.
- ☒ Claim(s) 1-12 AND 14-32 is/are allowed.
- ☒ Claim(s) 33-42 is/are rejected.
- ☒ Claim(s) 13 is/are objected to.
- ☐ Claim(s) \_\_\_\_\_ are subject to restriction or election requirement

## Application Papers

- ☐ The proposed drawing correction, filed on \_\_\_\_\_ is ☐ approved ☐ disapproved.
- ☐ The drawing(s) filed on \_\_\_\_\_ is/are objected to by the Examiner
- ☐ The specification is objected to by the Examiner.
- ☐ The oath or declaration is objected to by the Examiner.

## Priority under 35 U.S.C. § 119 (a)-(d)

- ☐ Acknowledgement is made of a claim for foreign priority under 35 U.S.C. § 119 (a)-(d).
- ☐ All ☐ Some\* ☐ None of the:
  - ☐ Certified copies of the priority documents have been received.
  - ☐ Certified copies of the priority documents have been received in Application No. \_\_\_\_\_.
  - ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a))

\*Certified copies not received: \_\_\_\_\_

## Attachment(s)

- ☒ Information Disclosure Statement(s), PTO-1449, Paper No(s). 4
- ☒ Interview Summary, PTO-413
- ☒ Notice of Reference(s) Cited, PTO-892
- ☐ Notice of Informal Patent Application, PTO-152
- ☐ Notice of Draftsperson's Patent Drawing Review, PTO-948
- ☒ Other COPIES of FAXES

Office Action Summary

DATED JAN. 27, 2003 AND  
FEB 27 2003

## **DETAILED ACTION**

### ***Drawings***

- a) Fig. 1 date-stamped Dec. 17, 2002 has been approved by the examiner.

### ***Claim Objections***

- a) In claim 13 line 3, "and" should be replaced with ",".

### ***Claim Rejections - 35 USC § 103***

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

The person having "ordinary skill in the art" has the capability of understanding the scientific and engineering principles applicable to the claimed invention. The references of record in this application reasonably reflect this level of skill.

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Claims 33-39 are rejected under 35 U.S.C. 103(a) as being unpatentable over U. S. Pat. 4,088,743 in view of pgs. 17, 25 and 26 in Fuel Flue Gases: The Application and Interpretation of Gas Analyses and Tests edited by C. George Segeler.

Fig. 2 illustrated in U. S. Pat. 4,088,743 illustrates what appears to be the same process for producing elemental sulfur from a gas containing not only hydrogen sulfide but also the same claimed olefins, etc. (please see col. 15 Ins. 55 et seq. in U. S. Pat. 4,088,743 and please also note that col. 2 Ins. 45-52 in U. S. Pat. 4,088,743 also sets forth that the process described therein may also treat sour refinery gases, etc., which are known to contain the same claimed olefins of at least applicants' claim 33, and the coke oven gases embraced in the scope of gases contemplated by U. S. Pat. 4,088,743 are also known to include the toluene and xylene of applicants' claim 39, as evinced by pgs. 17, 25 and 26 in the Fuel Flue Gases book edited by Segeler), comprising the steps:

passing the hydrogen sulfide-containing gas through contact condenser 80, where the gas is washed with acidified wash water at a temperature of 40 to 150 °F, wherein the wash water is rendered acidic by receiving a portion of wash water at a pH ranging from 5.5 to 7.5 via lines 210, 230, 120, 90 and then line 100 into the contact condenser 80 (please also see fig. 2 and col. 47-56 in U. S. Pat. 4,088,743), which is submitted to inherently remove the same hydrocarbons from the same gas to the same degree;

passing the washed, hydrogen sulfide-containing gas from the contact condenser 80 to oxidation reactor 25 via lines 150, 1, 15, 18 and 24, where the hydrogen sulfide is oxidized by the air introduced in line 20 to produce elemental sulfur, while the aqueous product is separated from the gas via line 110, which is discharged via line 20, in the manner set forth in at least applicants' claim 33.

The difference between the process described in fig. 2 and the process described in col. 15 lns. 55 et seq. in U. S. Pat. 4,088,743 is that applicants' claim 33 calls for the treatment of a gas containing unsaturated hydrocarbons, whereas the process described in col. 15 lns 55 et seq. in U. S. Pat. 4,088,743 describes the treatment of geothermal steam, which is only taught to contain methane.

Col. 2 lns. 45-61 in U. S. Pat. 4,088,743 sets forth that their process is applicable to the treatment of a variety of gases, in addition to the geothermal steam mentioned in col. 15, such as sour refinery gases, etc.

Pgs. 17 and 25 in the Fuel Flue Gases book set forth that sour refinery gases contain, not only hydrogen sulfide, but also propylene and ethylene, and pg. 26 in the

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Fuel Flue Gases book sets forth that coke oven gases contain, not only hydrogen sulfide, but also toluene, xylene, etc.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made *to modify* the process described in col. 15 Ins. 55 et seq. and also fig. 2 in U. S. Pat. 4,088,743 *by substituting* one of the feed gases described in col. 2 Ins. 45-61 in U. S. Pat. 4,088,743 *in lieu of* the geothermal steam expressly treated in the process described in col. 15 Ins. 55 et seq. in U. S. Pat. 4,088,743, in the manner embraced in the scope of at least applicants' claims 33 and 39, *because* the disclosure set forth in col. 2 Ins. 45-61 in U. S. Pat. 4,088,743 fairly suggests that the authors of this patent contemplated the treatment of these unsaturated hydrocarbon-containing feed gases mentioned in col. 2 Ins. 45-62 in U. S. Pat. 4,088,743.

Note that the washing water extracted from the "SO<sub>2</sub> scrubber" 180 is expected to inherently contain the same sulfuric acid recited in applicants' claim 34 in the same concentrations recited in applicants' claim 35, and produce the same sulfate salts recited in applicants' claim 34.

Note that the same sour refinery gas, etc. being treated by the process described in U. S. Pat. 4,088,743 is expected to inherently contain the same claimed unsaturated hydrocarbons in the same concentrations recited in applicants' claim 36, and that the gas is expected to inherently contain the same concentrations of unsaturated hydrocarbons after the aqueous washing step recited in applicants' claims 36-38.

Claims 33-42 are rejected under 35 U.S.C. 103(a) as being unpatentable over U. S. Pat. 4,088,743 in view of Fuel Flue Gases: The Application and Interpretation of Gas Analyses and Tests by C. George Segeler as applied to claims 33-39 above, and further in view of pgs. 18-84 to 18-90 in the Chemical Engineers' Handbook (5<sup>th</sup> ed.) by Perry et al.

The difference between the applicants' claims and U. S. Pat. 4,088,743 is that applicants' claims 40-42 call for passing the gas exiting the aqueous scrubber through a mist eliminator.

Pgs. 18-84 et seq. in the Chemical Engineers' Handbook describe the use of a variety of "impingement separators" (i. e. the applicants' mist eliminator) for removing unwanted mist out of a gas.

It would have been obvious to one of ordinary skill in the art at the time the invention was made *to modify* the process described in U. S. Pat. 4,088,743 *by subjecting* the washed gas exiting the contact condenser 80 to one of the mist eliminators described on pgs. 18-84 et seq. in the Chemical Engineers' Handbook, in the manner required by applicants' claims 40-42, *because* of the expected advantage of removing any mist entrained in the washed gas that managed to escape separation from the gas within the contact condenser 80.

Additionally, the limitation of wetting the mist eliminator with additional wash solution set forth in applicants' claim 42 is noted, but is obvious from pg. 18-87, 2<sup>nd</sup> column in the Chemical Engineers' Handbook, which teaches this same irrigation of the

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packing material within a packed bed separator for what appears to be same advantage of removing even more mist (or other components) out of the gas.

Claims 1-32 have not been rejected under either 35USC102 or 35USC103 because there is nothing in any of the references of record teaching or suggesting that the "tail gas" (48) illustrated in fig. 3 in U. S. Pat. 5,851,265 should replace the "air" (20) illustrated in fig. 2 in U. S. Pat. 4,088,743 and also that the "SO<sub>2</sub> absorber/SO<sub>2</sub> stripper" system illustrated in fig. 3 in U. S. Pat. 5,851,265 should replace the "SO<sub>2</sub> scrubber" (180) illustrated in fig. 2 in U. S. Pat. 4,088,743 in a manner rendering obvious (or, alternatively, arriving at) the invention of applicants' claim 1: please see the discussion of the *In re Lintner* 458 F.2d 1013, 1016, 173 USPQ 560, 562 (CCPA 1972) court decision set forth in section 2143.01 in the MPEP (8<sup>th</sup> ed.).

### ***Response to Arguments***

The applicants' arguments submitted in their Amendment dated Dec. 17, 2002 (paper no. 13) with respect to the rejection of claims 1-32 under 35USC103 over U. S. Pat. 4,088,743 in view of U. S. Pat. 5,851,265 have been found persuasive. The applicants' arguments with respect to claim 33 (and claims dependent thereon) are moot in view of the new grounds of rejection.




Art Unit: 1754

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Timothy C. Vanoy whose telephone number is 703-308-2540. The examiner can normally be reached on 8 hr. days.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stanley Silverman, can be reached at 703-308-3837. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9310 for regular communications and 703-872-9311 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0661.

Timothy Vanoy/tv  
March 4, 2003

  
Timothy Vandy  
Patent Examiner

Art Unit 1754

**TECHNOLOGY CENTER 1700  
COVER SHEET**

DATE: Jan. 27, 2003

APPL. NO.

09-693,418

TO: Mr. Vincent Keil

Docket ENV 9851.8  
to Brian Burmaster et al.

FAX NUMBER: ~~231~~ 231-4342  
314.

PHONE NUMBER: 314. 231.5400

FROM: Tim Vanoy : ph. 703.308.2540

MESSAGE: Proposed Examiner's Amendment

NUMBER OF PAGES INCLUDING THIS ONE: 3

~~Tech Center 1700 Fax Number 703-305-3599 or Fax Number 703-~~

~~Tech Center 1700 Phone Number 703-308-0661~~

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*P R O P O S E D*  
**Examiner's Amendment**

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

~~Authorization for this examiner's amendment was given in a telephone interview with Mr. Vincent Keil, applicants' attorney, on Jan. 27, 2003.~~

The application has been amended as follows:

In claim 13 ln. 3, "and" has been replaced with --,--.

Claims 33-42 have been canceled.

**Drawings**

The figure date-stamped Dec. 17, 2002 has been approved by the examiner.

**Examiner's Statement of Reasons for Allowance**

The following is an examiner's statement of reasons for allowance: There is nothing in any of the references of record teaching or suggesting that the "tail gas" (48) illustrated in fig. 3 in U. S. Pat. 5,851,265 should replace the "air" (20) illustrated in fig. 2 in U. S. Pat. 4,088,743 and also that the "SO<sub>2</sub> absorber"/"SO<sub>2</sub> stripper" system illustrated in fig. 3 in U. S. Pat. 5,851,265 should replace the "SO<sub>2</sub> scrubber" (180) illustrated in fig. 2 in U. S. Pat. 4,088,743 in a manner rendering obvious (or, alternatively, arriving at) the invention of applicants' claim 1: please see the discussion of the *In re Lintner* 458

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F.2d 1013, 1016, 173 USPQ 560, 562 (CCPA 1972) court decision set forth in section 2143.01 in the MPEP (8<sup>th</sup> ed.).

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Timothy C. Vanoy whose telephone number is 703-308-2540. The examiner can normally be reached on 8 hr. days.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stanley Silverman, can be reached on 703-308-3837. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9310 for regular communications and 703-872-9311 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-

REMARKS:

0661. REG. CLAIM 33, THE FEED GAS TO BE WASHED IS THE SAME AS THAT SET FORTH IN COL. 2 LNS. 45-52 IN U.S. PAT. 4,088,743. COMPARE THE SOUR NATURAL GAS, REFINARY GAS, ETC. ON PG. 11 LNS. 17 ET. SEQ. IN THE APPLICANTS' SPEC. TO THESE SAME GASES MENTIONED IN COL. 2 LNS. 45-52 IN U.S. PAT. 4,088,743.

Timothy Vanoy/tv

January 27, 2003 THE SCRUBBING SOL'N USED TO CLEAN THE FEED GAS IS THE SAME: COMPARE APPLICANTS' CLAIM 34 TO COL. 16 LNS. 47-56 (I.E. THE "COOLING WATER", THE "UNSATURATED HYDROCARBONS" ARE ADMITTED TO BE PRIOR ART IN THE PREAMBLE OF APPLICANTS' CLAIM 33.

Respectfully  
Jew

# TECHNOLOGY CENTER 1700 COVER SHEET

DATE: Feb 27 2003

APPL. NO.

09-693,418

TO: Mr. Vincent Kiel

FAX NUMBER: 314.231.4342

PHONE NUMBER: 314.231.5400

FROM: Tim Vandy ph 703.308.2540

THE ENCLOSED PORTIONS OF "FUEL FLUE GASES..."  
IS EVIDENCE THAT (AT LEAST) THE "SOUR REFINERY GASES" MENTIONED

MESSAGE: IN COL. 2 LN. 52 IN U S PAT. 4,088,743 CONTAINS  
ETHYLENE AND ACETYLENE.

ALSO NOTE THAT "COKE OVEN GASES" IS TAUGHT TO INCLUDE THE SAME  
XYLENE, BENZENE, ETC... MENTIONED ON PG. 12 IN APPLICANTS' SPEC.,

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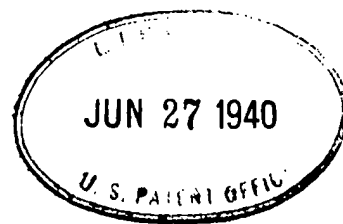
—RESPECTFULLY—  
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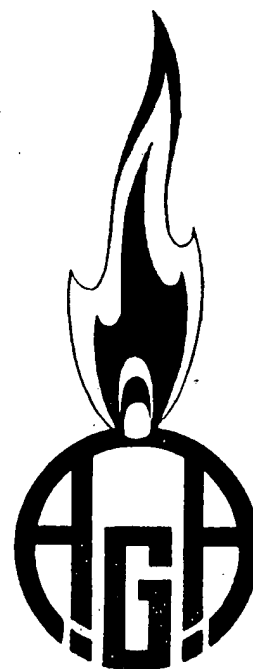
Segeler, Curt George



# FUEL LUE *Gases*

The Application and Interpretation  
of Gas Analyses and Tests

AMERICAN GAS ASSOCIATION  
420 Lexington Avenue, New York, N. Y.  
1940



Prepared under the auspices of the Subcommittee of the Chemical  
Committee, Technical Section, American Gas Association.

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J. F. ANTHES, *Past Chairman*

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Approved by the Advisory Committee, Technical Section, American Gas Association.

E. C. UHLIG, *Chairman*

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C. GEORGE SEGELER

*Editor*

Five Dollars

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## B. DISTILLATION METHODS<sup>1</sup>

Apparatus described under the previous paragraphs will not separate quantitatively the homologous series of gases such as ethane, propane, butane, etc., or the similar unsaturated compounds and, therefore, recourse must be had to other methods. In the case of the two series of compounds mentioned and similar gases, a very efficient fractionating column still can be adapted to determine small amounts of samples containing these constituents with precision. This method can be used together with absorption methods for the complete determination of mixed gases. The best known of the apparatus using fractionation at low temperatures and low pressures is the Podbielniak equipment. The distillation methods may be used for the analyses of natural gas, natural gasoline, and other hydrocarbon mixtures. Other types of apparatus operating in a similar manner are the Burrell and Seibert, Sheppard and Porter,<sup>2</sup> and Phillips Petroleum.<sup>3</sup>

### a. SYNOPSIS OF PROCEDURES<sup>4</sup>

Two classes of procedures are employed as follows:

Class I. Methods based on the *distillation* of sample from one bulb, maintained at a definite low temperature sufficient to condense the sample wholly or in part to another bulb maintained at a definite lower temperature. The apparatus is arranged to permit repeated distillation of the sample or sample fractions, according to some definite scheme of distillation temperatures and pressures and sequence of distillation. A fractionating column is not used and dependence is placed on repeated distillation at low pressure to secure the required separation of hydrocarbons.

Class II. Methods based on the use of a *fractionating* column, usually vacuum jacketed, to accomplish the separation of hydrocarbons in the sample in a single or sometimes double analytical distillation.

### b. ERRORS IN DISTILLATION METHODS

Since the Podbielniak equipment is the typical commercial apparatus employed, consideration of its accuracy may be helpful. In order to obtain final percentage results accurate to the order of 0.1%, there

<sup>1</sup> "Report of Subcommittee on Analysis of Liquefied Petroleum Gases by Low Temperature Fractionation," A.G.A. Proc., 1931, pp. 1034-49. This includes reference to many other sources.

<sup>2</sup> Designed for reference, standardization, and investigation work. Its relatively complicated procedures make it unsuited for field testing or ordinary plant control.

<sup>3</sup> Time required for analysis from 3½ to 6 hrs. but the equipment is well suited for natural gases. It yields very good separation of the individual fractions.

<sup>4</sup> Handbook of Butane-Propane Gases, Second Edition, Chapter 5, p. 56.

must be a sharp fractionation in a relatively short time, especially when the mixture contains components which boil within 20° F. of each other. Considerable difference in accuracy results from the use of distilling tubes of various inside diameters but, in general, proper operation of the apparatus with standardized procedures will permit check on duplicate determinations from a few hundredths of a per cent to 0.3% or more, procedure depending upon the size of the sample and upon the amount and ease of separation of the component determined. When accurate physical constants are available for interpretation of the analytical results, the absolute accuracy of the results should also run within similar limits. The results of fractional distillation will not check directly with the results of slow combustion analysis. This is because slow combustion determines a mixture of homologous hydrocarbons as two equivalent hydrocarbons and the other hydrocarbons in the sample are determined in terms of these two. Mathematical relations are available for converting one to the other with fair accuracy if desired.<sup>1</sup>

Reference should also be made to paragraph b.—"Errors of Confining Liquids"—given under the previous section on absorption methods because this material is applicable to some of the sampling procedures which may be involved when using distillation analyses.

Errors due to solubility can occur when storing samples of gases containing propane, butane, or certain other gases in the presence of rubber or grease. The problem is analogous to solubility of gases in confining liquids.

### c. CLASSIFICATION OF GASES

By dividing gases into four groups without too sharp a distinction between them, distillation methods may be applied in combination with other methods to a very wide range of mixtures. The four groups for which the procedures are specially adapted are as follows:

Group 1. Gases containing in excess of 10% methane and lower boiling components, also appreciable quantities of ethylene, acetylene, ethane, propylene, propane, etc., or when both the saturated and unsaturated series are to be determined individually by combined low temperature fractionation into simpler groups followed by subsequent chemical tests. The following gases will usually be included in this group when complete analysis is desired:

Reformed gas—natural or refinery.	compare to the refinery gas mentioned in col. 2 h. 52 in U S 4088 743
Carburetted water gas.	
Coke oven gas, and, in general,	
Manufactured gases.	
Cracked refinery gases.	
Oil gas.	

<sup>1</sup> Handbook of Butane-Propane Gases, Second Edition, p. 74.



TABLE 20—OIL REFINERY GAS ANALYSES

Combination of Hempel and Podbielniak Analyses				
Propylene	5.3	17.4	9.7	4.1
Ethylene	4.0	20.7	3.8	1.7
Hexane	...	...	...	4.1
Pentane	...	...	...	3.7
Butane	8.5	...	9.4	14.9
Propane	17.0	...	15.1	17.6
Ethane	19.2	17.6	22.6	21.0
Methane	41.6	34.9	34.2	26.9
Carbon monoxide	1.6	1.5	1.5	0.9
Hydrogen	1.4	4.2	1.2	1.0
Carbon dioxide	0.2	0.7	0.4	0.5
Oxygen	0.2	0.1	0.4	0.2
Nitrogen <sup>a</sup>	1.0	2.9	1.7	3.4
Total	100.0	100.0	100.0	100.0
B.t.u.	1634	1407	1699	2010
Sp. gr.	1.01	0.886	1.07	1.25

<sup>a</sup> By difference, and includes  $H_2S$ ,  $CS_2$ , etc.

Table 21 shows sample analyses of 530 B.t.u. reformed gas produced from oil refinery gas and from natural gas sources. The amounts of generator fuel and the therms of original gas used per MCF of finished gas are shown.

TABLE 21—530 B.T.U. REFORMED GAS ANALYSES

	From Oil Refinery Gas			From Natural Gas	
Illuminants	3.5	5.6	5.7	0.6	0.2
$CH_4$	17.4	13.5	12.3	27.0	28.0
$C_2H_6$	2.3	3.3	3.3	2.9	5.2
CO	17.9	22.1	24.1	15.4	20.5
$H_2$	53.0	39.6	40.4	47.2	29.6
$CO_2$	2.5	3.4	3.6	2.2	3.2
$O_2$	0.1	0.1	0.2	0.1	0.1
$N_2$	3.3	12.4	10.4	4.6	13.2
Total	100.0	100.0	100.0	100.0	100.0
B.t.u.	530	530	530	530	530
Sp. gr.	0.458	0.614	0.624	0.449	0.608
Fuel, lbs. per MCF	7.3	12.8	15.7	6.0	14.0
Gas, therms per MCF	5.09	4.35	4.07	4.95	4.09

#### b. REFORMED NATURAL GAS<sup>1</sup>

See also preceding paragraphs on reformed refinery oil gas. The pyrolysis of natural gas on contact with

- <sup>1</sup> Valuable information is available in reports presented by:  
H. L. Masser, "Reforming of Natural Gas," P.C.G.A., 1924.  
W. W. Odell, "Reforming Natural Gas," U. S. Bur. of Mines, 1929.  
Frank Wills and D. J. McCarthy, "Reforming Natural Gas in Two Shell Generator," P.C.G.A., 1930.  
C. A. Schlegel, "Economics of Reforming Refinery Gas," A.G.A. Prod. Conf., 1930.  
R. H. Burdick, "Natural Gas Reforming at Toledo," A.G.A. Prod. Conf., 1931.  
H. G. Terzian, "U.G.I. Reforming Process at Chester," A.G.A. Prod. Conf., 1931.  
J. A. Perry, "Reforming Oil Refinery and Natural Gas," Canadian Gas Assn., 1933.  
H. J. Wiedenbeck, "Production of Reforming Natural Gas," A.G.A. Prod. Conf., 1934.

hot checker brick results first in decomposition of less stable ethane forming methane and freeing  $H_2$  and some C. The second stage is the breakdown of methane to C and  $H_2$ . Masser<sup>1</sup> reported on the details involved in reforming natural gas on checker brick in oil gas sets using 1200 B.t.u. natural gas.

The General Oil Gas Corporation reported on the Faber-Dayton process<sup>2</sup> at Olean, New York, where 1340 B.t.u. natural gas was reformed to various finished gases.

The Odell process was in use on a commercial scale<sup>3</sup> producing reformed gases as indicated in Table 21. The references cover examples of operation with recovery and with elimination of carbon black.

Cracking natural gas in a water gas generator has been described by J. S. Duesler.<sup>4</sup>

#### c. REFORMED BUTANE GAS<sup>5</sup>

Typical compositions of these gases have not been included in the summary table because the processes are not in commercial use at this time although they have been extensively studied along with the reforming operations on other gaseous hydrocarbons. The references cited give interesting data on chemical reactions, probable composition and yields, as well as properties of the reformed gases.

#### E. OIL GAS

Oil gas is a combination of cracked oil vapors and blue gas produced by reactions analogous to those involved in the production of carburetted water gas, which will be considered later, except that the oil gases predominate and the blue gas is present in much smaller quantities. By-product carbon or lampblack is produced in considerable quantities. Broadly speaking, two types of equipment are used: the "straight shot" and the Jones process.

The introduction of natural gas in the larger centers on the Pacific Coast has decreased the use of this type of gas so that little is now made except in the Pacific Northwest. Nevertheless, as recently as 1930, an important modification of the process was tried out with success.<sup>6</sup> Previously, low cost oil available on the West Coast was the reason for the economy of the oil-gas process and the failure to attack its wasteful feature, the formation of lampblack. Most of the lampblack

<sup>1</sup> Gas Age-Record, Aug. 2, 1924, p. 143.

<sup>2</sup> A.G.A. Proc., 1930, pp. 1482-87.

<sup>3</sup> Operating results for Toledo, Ohio, using the Odell process are given in a paper by R. H. Burdick, A.G.A. Prod. & Chem. Conf., 1931.

<sup>4</sup> A.G.A. Proc., 1930, pp. 1488-90.

<sup>5</sup> W. W. Odell, "Reforming Gaseous Hydrocarbons," Amer. Petrol. Inst. Proc., 1932, pp. 23-31.

<sup>6</sup> W. F. Faber, "Reformed Butane," Gas Age-Record, June 18, 1932, pp. 759-60; A.G.A. Proc., 1933, pp. 793-94.

<sup>7</sup> San Diego results, A.G.A. Proc., 1930, p. 1349.

was burned as boiler fuel rather than sold. Analysis of a typical oil gas is given in Table 14 in which it will be seen that this gas has a much lower specific gravity than the analogous carburetted water gases. It is also lower in illuminants and considerably higher in hydrogen and methane.

#### F. GASES FROM CARBONIZING OF COAL

A large variety of gases with different compositions and heating values is obtained by the destructive distillation of coal by heat out of contact with air or oxygen. This process, known as carbonization, yields a solid residue with a higher percentage of carbon than the original coal. Bituminous coals (gas coals in particular) are used, resulting in gases of different composition depending upon the equipment, temperatures, and the process of manufacture. Typical analyses are included in Nos. 22 to 27 in Table 14. The coal gases were at one time the principal manufactured gases in the United States, but at present a greater amount of carburetted water gas is produced, although a decided trend back to coke oven gas can be noticed.

##### a. COAL GASES

The four types of coal gases shown differ but slightly from one another except that the gas from vertical retorts generally has a lower heating value, a higher percentage of hydrogen, and, possibly, a higher percentage of carbon monoxide because of the practice of steaming the retorts. In addition, due to the diluting and sweeping action of the volume of gas formed, vertical retorts yield more tar and ammonia when the amount of steaming is increased. The analysis shown in Table 14 is that of the finished gas as served to the customer. Actually, as the gas comes from the retorts, it contains other constituents which will be considered in Chapter V.

##### b. COKE OVEN GAS

Although produced in an analogous manner to retort coal gases, the size of the charge, the operating temperatures, and other features of the process are different, tending to produce larger amounts of by-products and a more uniform coke. The composition of the finished gas is not very different. It may be of interest to consider the complete analysis of coke oven gas as determined by the Bureau of Mines.<sup>1</sup>

The gases (under the term "Illuminants" in Table 14) may contain a wide variety of constituents. The principal ones are ethylene, propylene, butylene, benzene, toluene, xylene, and acetylene. The exact proportion of each varies with the process. Since the usual methods of gas analysis do not separate these constituents, they are determined as one and this affords no basis for

<sup>1</sup> Bulletin 301.

calculating such values as specific gravity or heating value. The procedure usually followed is to assign a composite value for illuminants determined by the difference between the sum of the calculated values for the more accurately determined constituents such as carbon monoxide, hydrogen, methane, and ethane, and the heating value determined directly by a calorimeter. Table 22 is based on the Bureau of Mines' determinations using fractional distillation at low temperatures.

TABLE 22—ANALYSIS OF COKE OVEN GAS

Component	Gas from Koppers Ovens		Mixed Coal and Water Gas
	Unwashed	Debenzolized	
H <sub>2</sub> S	0.7	0.7	...
CO <sub>2</sub>	1.7	1.5	2.6
N <sub>2</sub>	0.9	1.0	4.2
H <sub>2</sub>	56.7	57.2	37.3
CO	5.7	5.8	13.3
CH <sub>4</sub>	29.6	29.2	31.1
C <sub>2</sub> H <sub>6</sub>	1.28	1.35	2.1
C <sub>2</sub> H <sub>4</sub>	2.45	2.50	6.1
C <sub>3</sub> H <sub>8</sub>	0.08	0.11	0.43
C <sub>3</sub> H <sub>6</sub>	0.34	0.29	0.60
C <sub>4</sub> H <sub>10</sub>	0.02	0.04	...
C <sub>4</sub> H <sub>8</sub>	0.16	0.18	0.11
C <sub>2</sub> H <sub>2</sub>	0.05	0.05	...
Light oil fraction	0.65	0.13	1.33

##### G. PRODUCER GAS

Producer gas differs from the preceding gases in being made by partial combustion of the coal or coke used as generator fuel. Producer gas is high in nitrogen which is introduced by the air brought in for combustion. The heating value is low; the specific gravity is high, and the per cent of inerts is high. It is often practically odorless and contains about 23–27% of carbon monoxide.

The composition of producer gas is influenced to a great extent not only by the raw materials and operating cycles used, but by the mechanical equipment involved. The high volatile content of bituminous coal requires a different technique than when anthracite or coke is used as a generator fuel. The resultant gases from these two fuels are quite different. Some steam is generally added in producer operation, introducing blue gas in the finished product.

Producer gas may be used as it comes from the generator ("hot producer gas") or tar and other impurities may be scrubbed out yielding "cold clean producer gas."

##### H. BLAST FURNACE GAS

One by-product from the operation of a blast furnace used in the manufacture of pig iron is called blast furnace gas. It is derived from the partial combustion of coke. Because of the high temperatures needed for making iron, the gas contains 27% carbon monoxide